Hands on 3D printed learning tools for tactile literacy

SPEVI 2020 Workshop

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https://www.monash.edu/it/hcc/research/inclusive-technologies

&

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Abstract

3D printing offers a new format for the creation of accessible materials for students who are blind or have low vision. Particularly for younger learners, the 3D format may be more readily understood than tactile graphics, offering a more engaging product that can be shared with sighted classmates.

In this hands-on workshop, participants will be invited to touch and play with a range of 3D printed models designed or printed for vision impaired students. Which of these models would work well in your classrooms? How could the models be improved? What else would you like to have made? Is 3D printing a practical solution for creation and distribution of materials in schools?

Workshop participants will be invited to input into the research project by providing feedback in the workshop and beyond.

Investigating 3D printing for accessible graphics

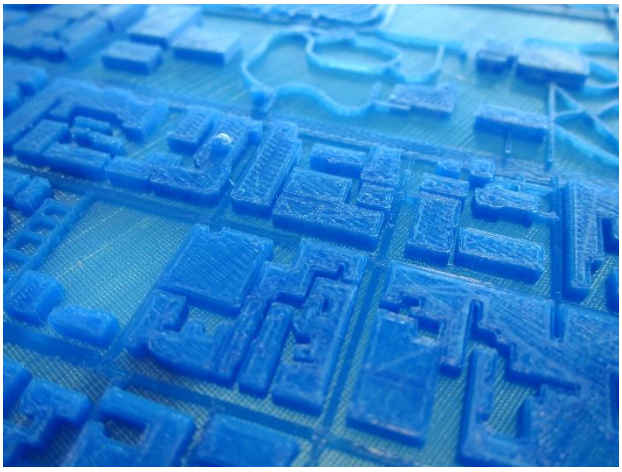
We are conducting a 3 year project, which started in October 2018, investigating the use of 3D printing for access to graphics by people who are blind or have low vision. The project is funded by the Australian Research Council and administered by Monash University. The Chief Investigators are Prof Kim Marriott and Dr Matthew Butler, and the project administrator is

Leona Holloway. All are members of the Inclusive Technologies group within the Faculty of Information Technology.

It is a Linkage Project, with emphasis on researchers and the community working together. We are extremely grateful for the support of our partners, each of which is making cash and/or in-kind contributions:

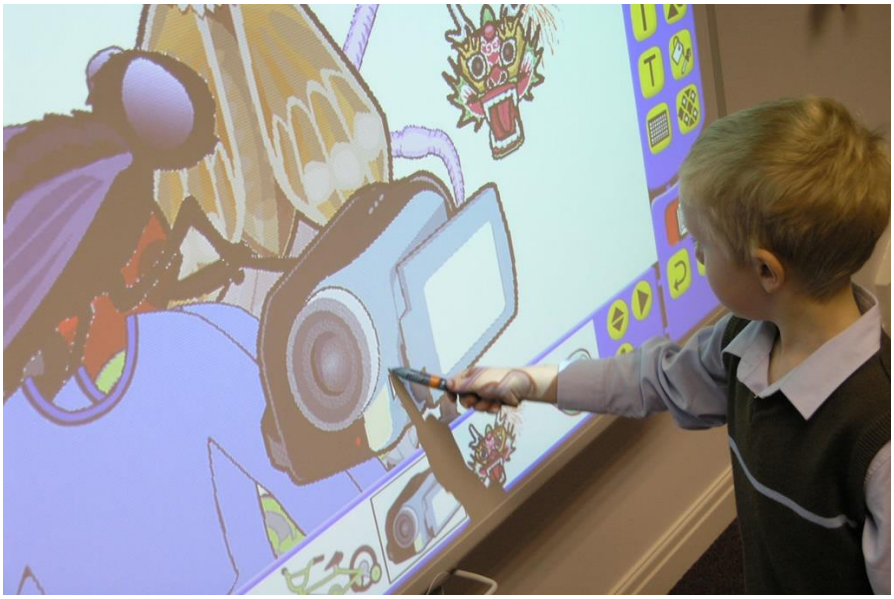
- Round Table on Information Access for People with Print Disabilities, with support from its members including SPEVI.
- Department of Education and Training, Victoria. Debra Lewis of the Statewide Vision Resource Centre (SVRC) is a Partner Investigator.
- Royal Institute for Deaf and Blind Children (RIDBC). Sonali Marathe is a Partner Investigator.
- Royal Society for the Blind of South Australia (RSB)
- Guide Dogs Victoria (GDV)

The focus of the project is on 3D printing for education materials and maps for orientation and mobility (O&M). In this workshop, we will focus on education.



(lots of) Graphics in the Classroom

Graphics are increasingly used in the classroom. With the print media revolution, graphics are used to summarise concepts and data (a picture tells a thousand words), to support diverse learning styles and to capture attention. What's more, these graphics do not just appear on the printed page with the use of multi-media in the classroom, such as interactive whiteboards and educational packages on the iPad.



However, while graphics hold advantages for sighted students, they can instead create barriers for students with a vision impairment. If a picture tells a thousand words, it is sometimes very difficult to translate to a written or verbal description. This is particularly the case for graphics with a spatial component. These and information graphics should be produced as a tactile graphic, which can be a time-consuming process and still requires interpretation for simplification. And even a good quality tactile graphic can be difficult to interpret by touch, requiring the student to have mastered tactual discrimination, use of a systematic search strategy, and memory to build up a concept of the overall picture from the series of small areas that they can explore with the fingertips at one time.

NAPLAN

One of the motivating factors for the development of tactile graphicacy skills (ability to derive meaning and understanding from an item through the sense of touch) is NAPLAN.

Whatever we think of benchmarking and national assessment, all students are expected to participate in NAPLAN testing. NAPLAN – National Assessment Program – Literacy and Numeracy.

Testing takes place in four areas or “domains”: Reading, Writing, Language Conventions (spelling, grammar and punctuation) and Numeracy at years 3, 5, 7 and 9.

YEAR 3 NUMERACY

1 Some students voted for their favourite animal.

FAVOURITE ANIMAL	
Animal	Tally
Cat	𝍸 |
Dog	𝍸 ||
Fish	|||
Horse	𝍸 𝍸 |

How many students voted for Horse?

9 ○ 10 ○ 11 ○ 12 ○

2 Which of these pictures shows a cylinder?

○ ○ ○ ○

In the NAPLAN year 3 numeracy test question shown below, the student is shown a picture of an ice cream cone and then asked to identify which shape represents the top view.

YEAR 3 NUMERACY

11 43 – 27 = ☐

12 Look at this picture of a cone.

Which one of these shows the top view?

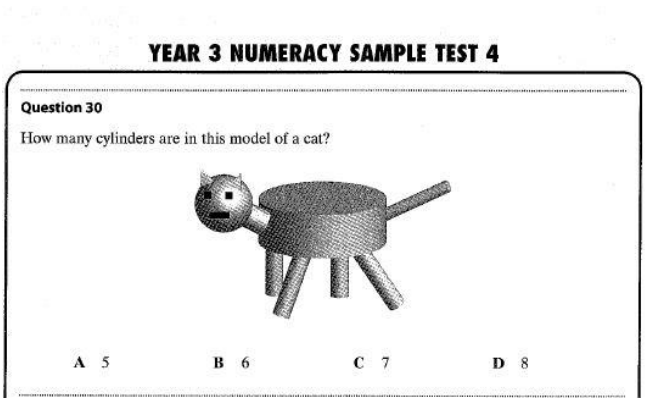
○ ○ ○ ○

In order to answer this question, the student must have an understanding of the qualities, features and attributes of a cone. How would you learn this? How does a tactile graphic representing a cone relate to the real object? How can a vision impaired student correctly answer a question such as this?

3D printed shapes for NAPLAN

We have used 3D printing to create 3D models that can accompany tactile graphics to assist students in understanding the concepts required to answer some of these NAPLAN questions.

Example 1: The question asks “How many cylinders are in this model of a cat?” and shows an image of a simplified cat made from 3D shapes with shading. It would be extremely difficult to adequately convey this graphic as a tactile diagram. However, it was quite easy to model a 3D printed equivalent (with just a couple of simplifications) which can be successfully used by a blind student to independently answer the question and demonstrate their knowledge of 3D shapes.

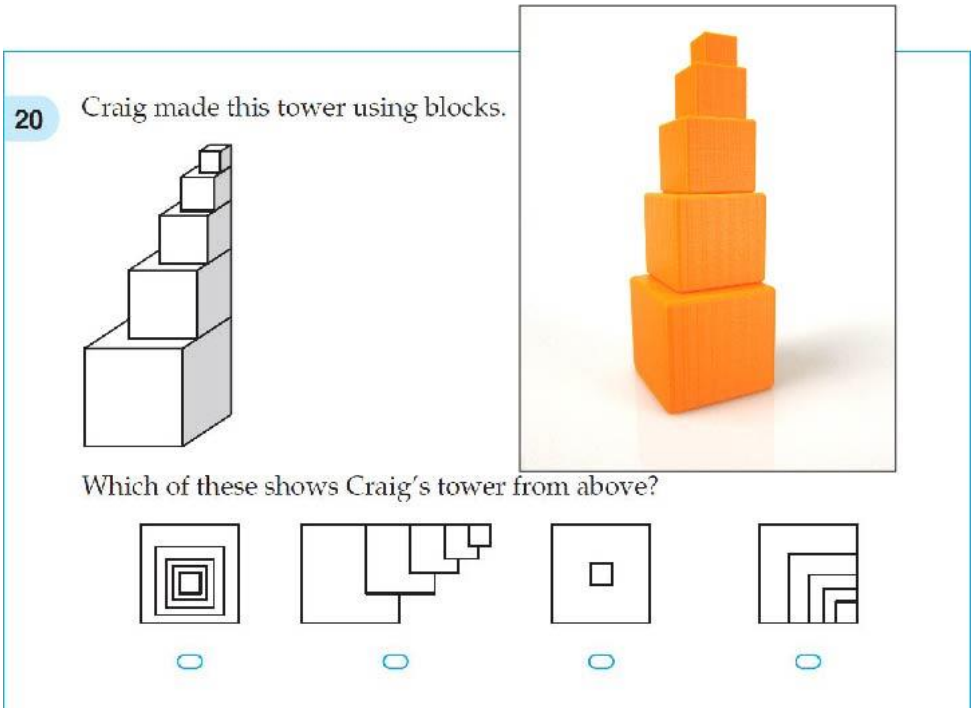

YEAR 3 NUMERACY SAMPLE TEST 4

Question 30

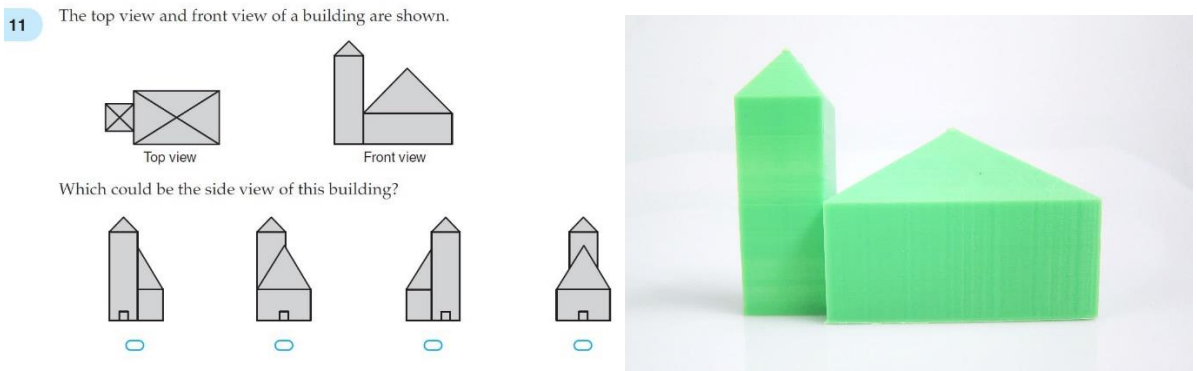
How many cylinders are in this model of a cat?

A 5 B 6 C 7 D 8

Example 2: A tower of blocks is illustrated as a 3D projection. As the tower goes up, each successive block is smaller than the last. Which of these 2D outlines shows the tower from above? Again, this question would be almost impossible to convey as a tactile graphic but was very easy to create as a 3D printed model. The potential answers can be presented as a tactile graphic, but the student will need to understand concepts of projection in order to answer correctly.

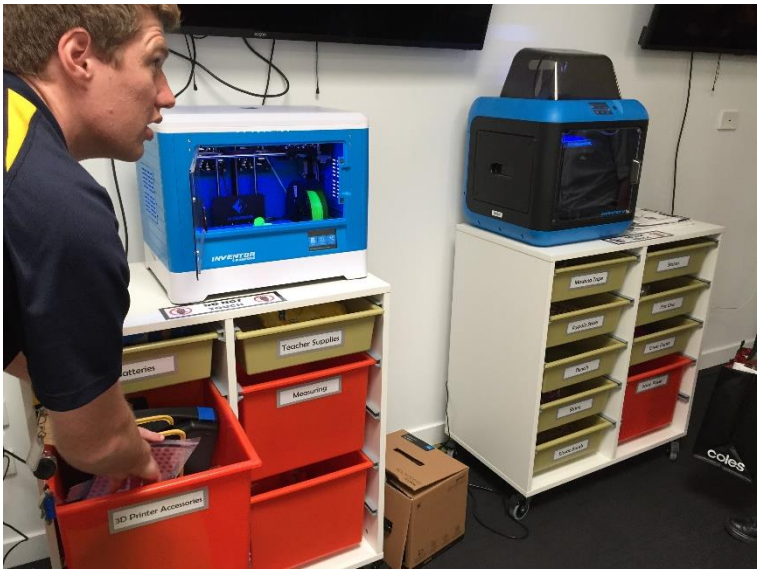


Example 3: The top view and front view of a building are shown as 2D projections. The Building consists of a tall square tower with pointed roof at one end of a rectangular main building with lower pointed roof. Which could be the side view of this building? While this question and answer use 2D diagrams and could easily be represented using a tactile graphic, the concept of projection is extremely difficult for a blind child. We produced the tower and main building as two separate 3D printed pieces that can be rearranged by hand to try to match the projections from each angle.



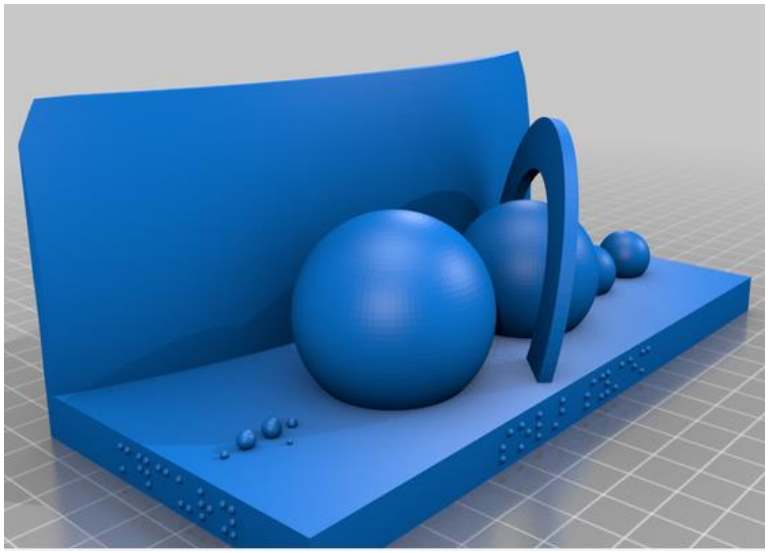
3D printing in Victorian schools and at SVRC

Thanks to some generous funding, 3D printers are now available at SVRC and many Victorian schools. Schools can apply to the SVRC Technology Library for a 3D printer (along with other low vision and blindness-related technology supports).

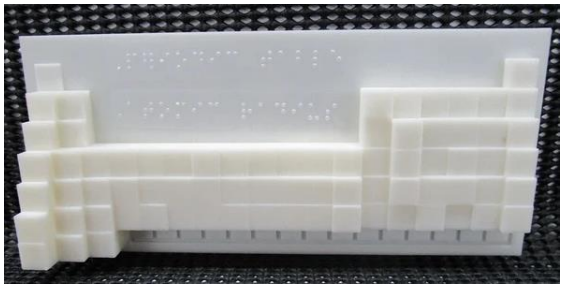
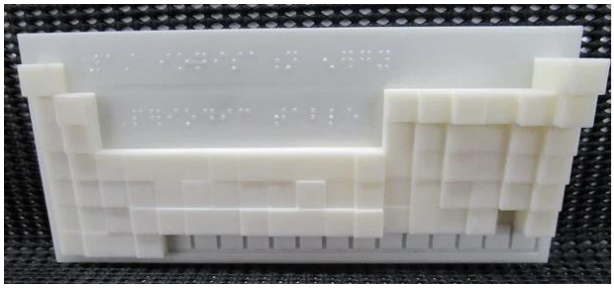


Staff of the SVRC are creating 3-D printed models to support tactile graphics for students in early and later secondary school.

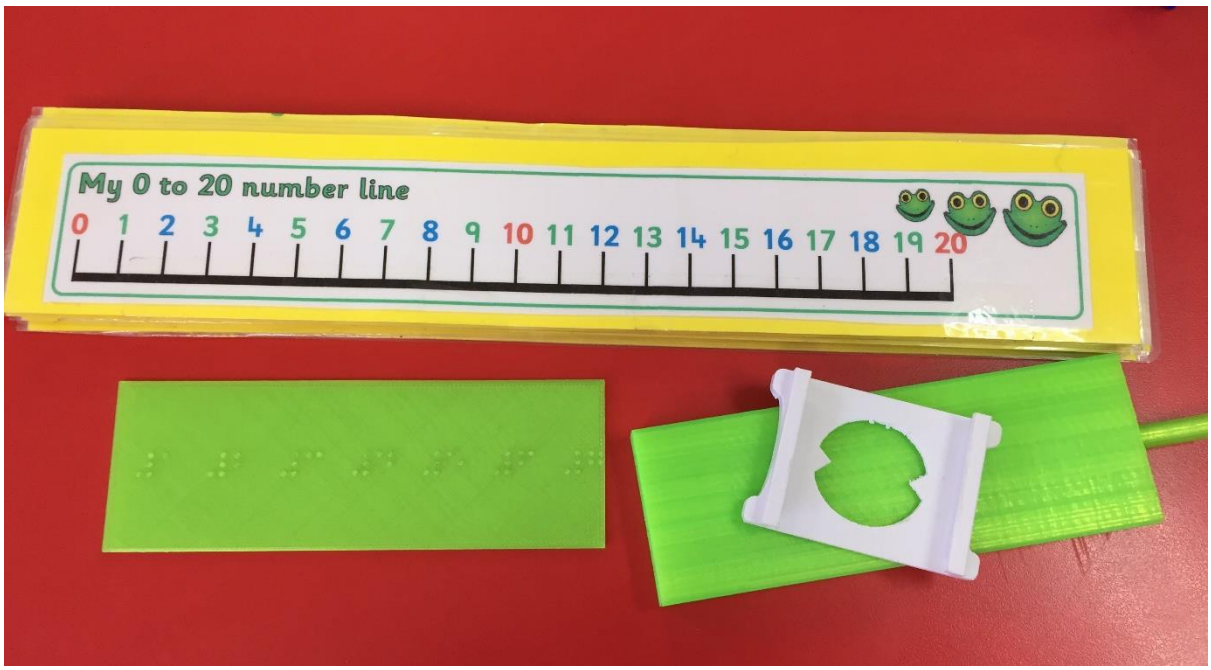
Example 1: A model of the solar system with planets of relative sizes and the sun represented as a curve, with braille labels. The student was provided with both a tactile graphic and the 3D model.



Example 2: The periodic table with relative height of each element adjusted to represent different features such as the atomic radius on one 3D print, or first ionization energy on a separate 3D printed model.

Some teachers have begun creating and printing their own materials too, such as this number line for a year 1 student.



Show & Tell

When are 3D printed models most useful?

Work done so far suggests that 3D printed models are most useful:

- To make learning more fun/engaging/inclusive
- To assist in understanding 2.5D tactile graphics
- To fill a gap
    - When tactile graphics are too difficult to understand
    - When other sources of 3D objects/models are not practical
        - Too difficult to find
        - Too delicate to touch

- Too expensive to buy
- Too dangerous to touch
- Too uncooperative (such as a wild animal)
- Too far away
- Too small to touch (such as a cell or an atom)
- Too big (such as a carnival ride)

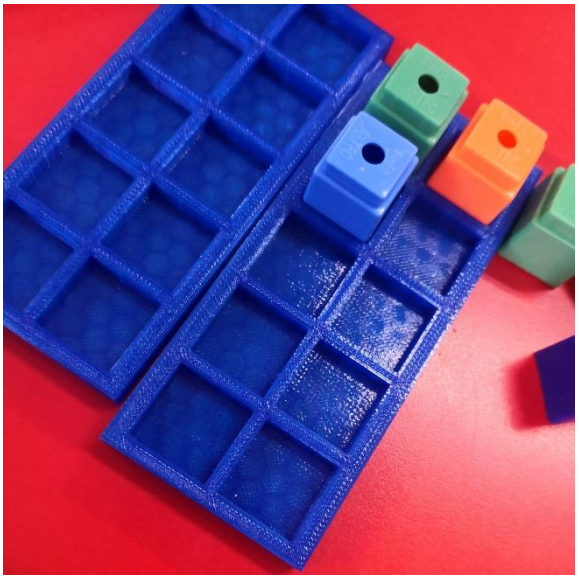
These are fairly abstract ideas on when and why 3D models might be useful in the classroom. But the purpose of today's workshop is to gather your perspectives as practitioners.

Show

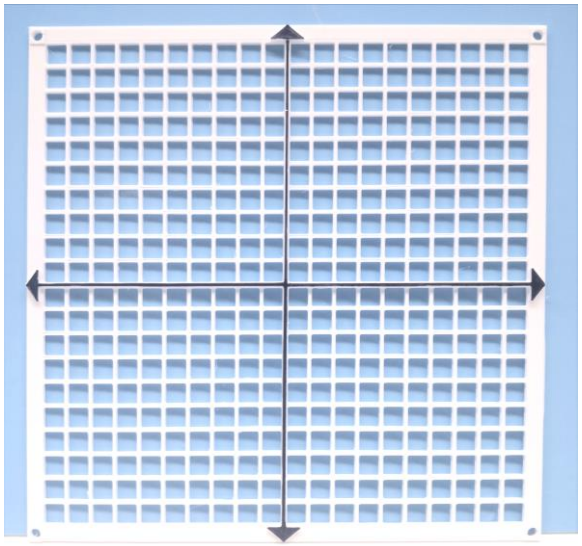
We have brought along a selection of models that we have printed or designed in response to requests or based on an examination of the curriculum. Some of these models are more useful than others. Let's take 5 minutes or so to look at (and touch) the models, handing them around so we all get to see a few. Almost all of these models can be found in the ANZAGG collections on Thingiverse at https://www.thingiverse.com/ANZAGG/collections.

1. Braille swing cell designed by RIDBC. It has 6 holes with pegs that can be moved to represent any braille cell, and a hinge to transform from the braille cell to the braille keyboard layout. The pegs are printed in a different colour to contrast against the base. Available for download from https://www.thingiverse.com/thing:2704904.

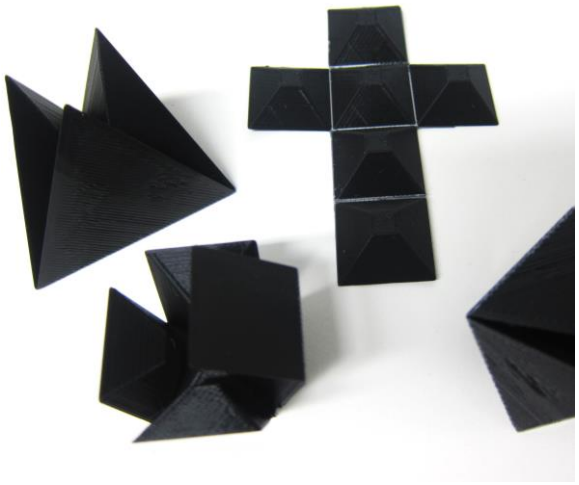
2. Tens frame with two rows of five and raised sides to hold the counters in place.



3. Braille quadrant graph math board, with a 10 by 10 grid and axis lines. This has been designed to be pinned onto cork board or similar material so the student can plot their own graphs using pins and string. Available for download from https://www.thingiverse.com/thing:2143865.

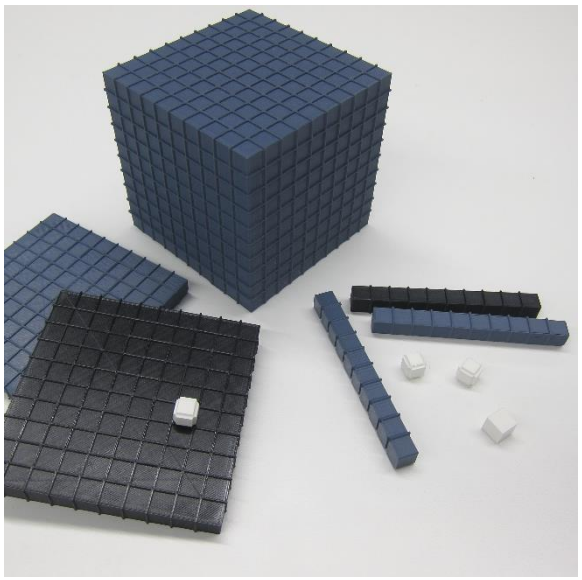


4. Foldable polyhedra, including a cube, square based pyramid and triangular based pyramid that lay out flat like a net then fold up to form the solid shape. Available for download from https://www.thingiverse.com/thing:2044034.



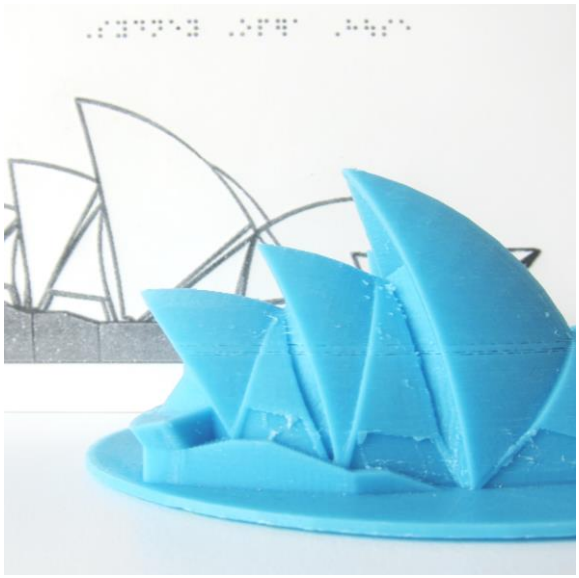
5. Fraction pies with braille labels added. Are these easier to access as kits or cardboard cut-outs? Available for download from https://www.thingiverse.com/thing:183108.

6. MAB or Base Ten Blocks with outward grooves to make the units easier to count by touch, as some students find the cut grooves in standard blocks too difficult to feel. Available for download from https://www.thingiverse.com/thing:3648003.



7. Alphabet blocks with raised print and braille. This raises the question of how to identify “which way up” 3D models should face. Available for download from https://www.thingiverse.com/thing:1702802.

8. 3D printed model of the Sydney Opera House, along with a tactile graphic depicting the side view. Available for download from https://www.thingiverse.com/thing:465989.



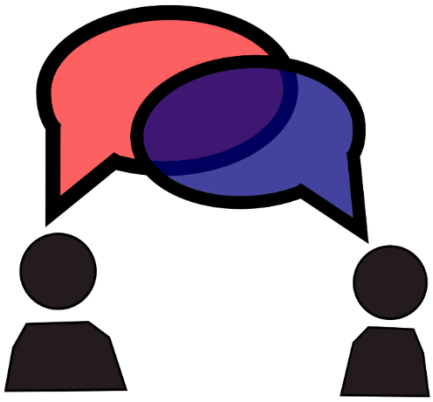
Many more models are also available to touch at the workshop.

Tell

Please give your honest opinions about the models you have felt.

- Which models are most useful?
- Which models are most engaging?
- Are there practical problems with any of the models? For example, do they need to be bigger? Is the texture too rough? Are they too fragile for use in the classroom? What labels are required?

- Which models are not needed because better options are available?



Survey

We are conducting an online survey to find out about what materials you currently use in the classroom and where 3D printing might provide additional assistance. This is where evidence-based learnings comes in. We need your participation to confirm or refute our expectations and to provide new insights.

Introducing braille cells

Item		Already using	Wanted
Not needed			
handmade representation of braille cell, e.g. muffin tray with balls			
purchased representation of braille cell			
3D printed braille fidget cube			
3D printed braille swing cell			
Tack-Tiles			
3D printed braille bricks			
3D printed braille building blocks			

Other:

Further information and links to the survey are given at http://accessiblegraphics.org/2019/12/18/survey/ The survey will be open for

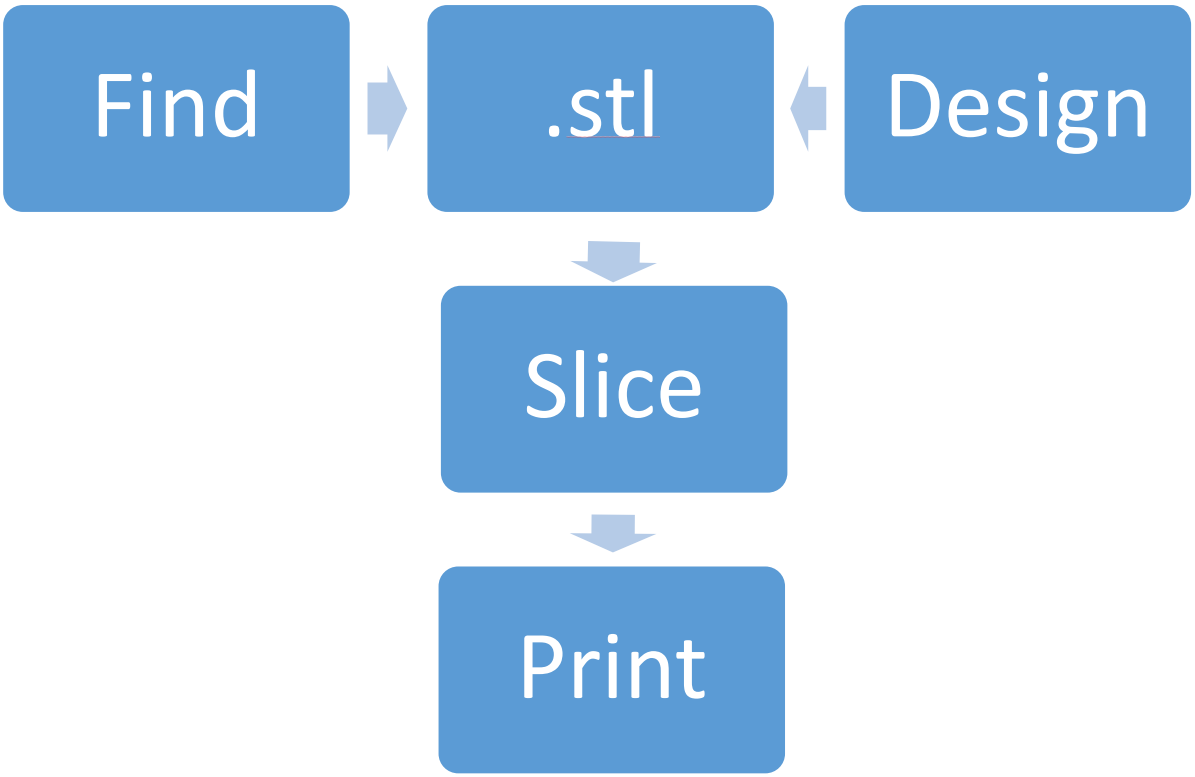
the first half of 2020 and we need as many responses as possible so that we can draw conclusions confidence. By completing the survey, you can also make suggestions for models that you would like us to create and sign up to test out models with your students.

3D printed kits for the curriculum

As a result of this workshop and the survey, we want to create kits of 3D printed materials for use in schools. The kits may be organized by year level or by subject area. We are aiming to distribute these kits for testing in the classroom and gather feedback for refinement.

Getting started with 3D printing

The 3D printing process



3D printing may be done at your school, by your education department alternative print service (Vic & NSW) or through a commercial service.

The first step is to look for an existing 3D model file. A lot are already available, for free.

If you can't find a suitable model, then you will need to design your own.

The end result will be a .stl or .obj file.

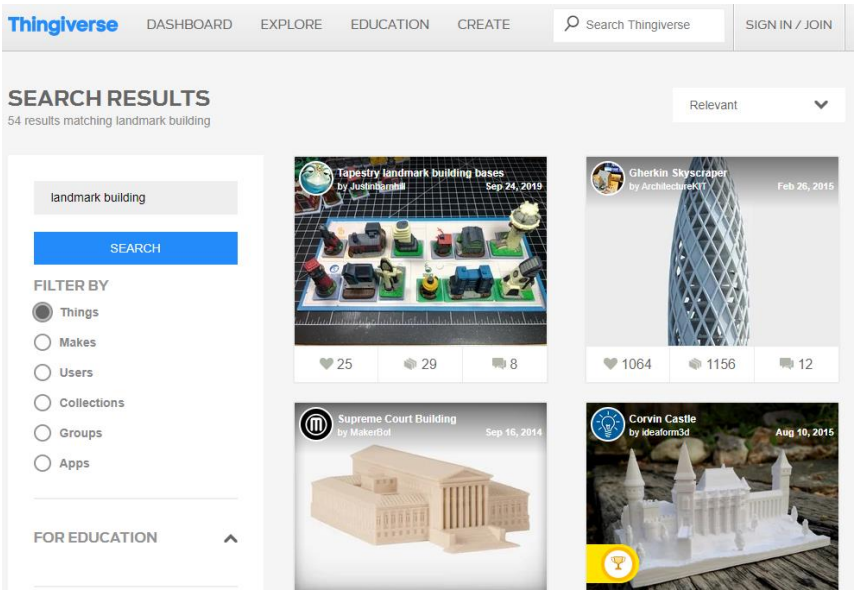
Your printer will come with software to load the 3D model file and make decisions about the printer, the level of detail, supports, etc. The software will then convert the model and your preferences into instructions for the printer, a step known as "slicing".

Finally, you will send the job to the printer. Be aware that most prints will take at least a couple of hours to complete, if not a whole day.

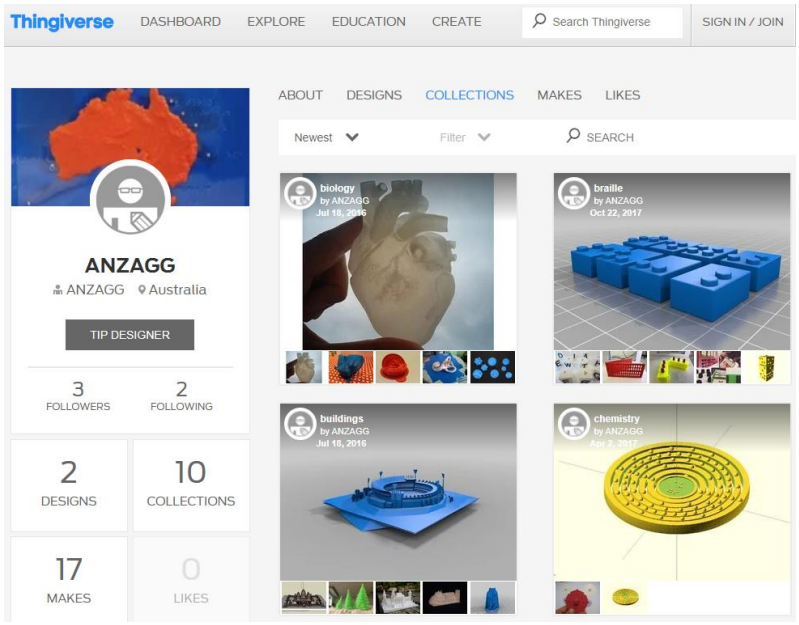
Find existing models

The 3D maker community is very open, with a lot of websites offering free models that you can download and print yourself.

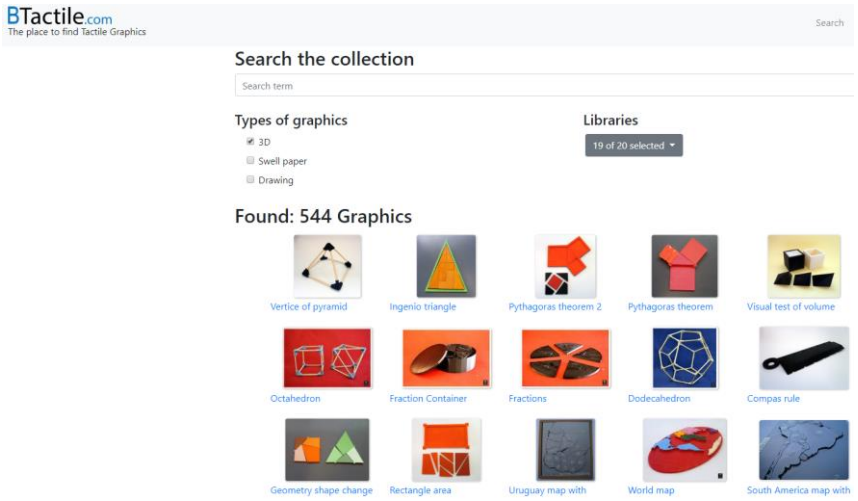
Thingiverse.com is probably the most well-known and widely used website for sharing and finding 3D printable models.



ANZAGG is the Australia and New Zealand Accessible Graphics Group. It is a subcommittee of the Round Table and open to anyone who is interested. It operates via listserv and Facebook discussion group. It also has web pages on printdisability.org and an account on Thingiverse at www.thingiverse.com/ANZAGG/collections. The ANZAGG Thingiverse account includes collections for braille, chemistry, biology, maps, mathematics and so on. All models are selected for touch readers and many have been tested by our group.



BTactile.com is a meta library, allowing you to search for tactile graphics and/or 3D models designed for touch readers from 20 different sources, including the ANZAGG Thingiverse collection.

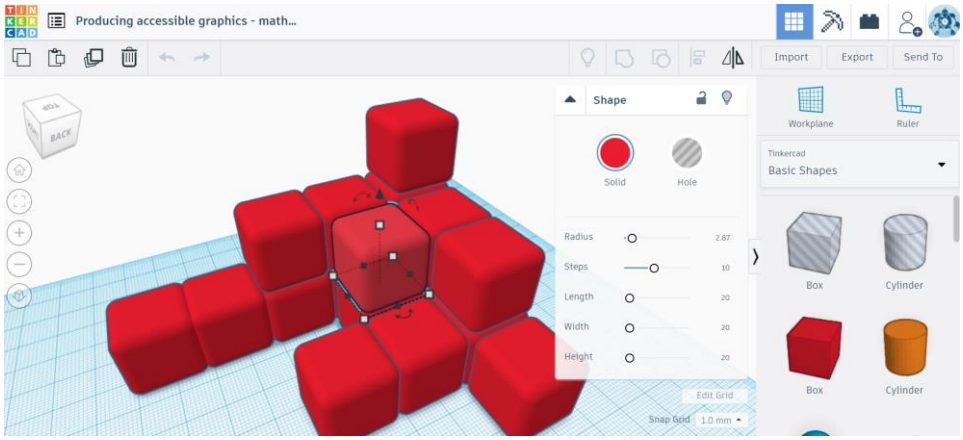


For more general models, you could also conduct a Google search including the term ".stl".

Design your own model

There is a wide choice of 3D modelling software, however most have a steep learning curve and many of them are very expensive. For the ARC project we have been focusing on TinkerCAD because it is very easy to use, it is free and it stores all of your designs online. TinkerCAD uses basic shapes and holes, with easy interface for adjusting size, alignment and joining. TinkerCAD is constantly adding new features, such as customisable complex shapes, kits, and build-your-own collections.

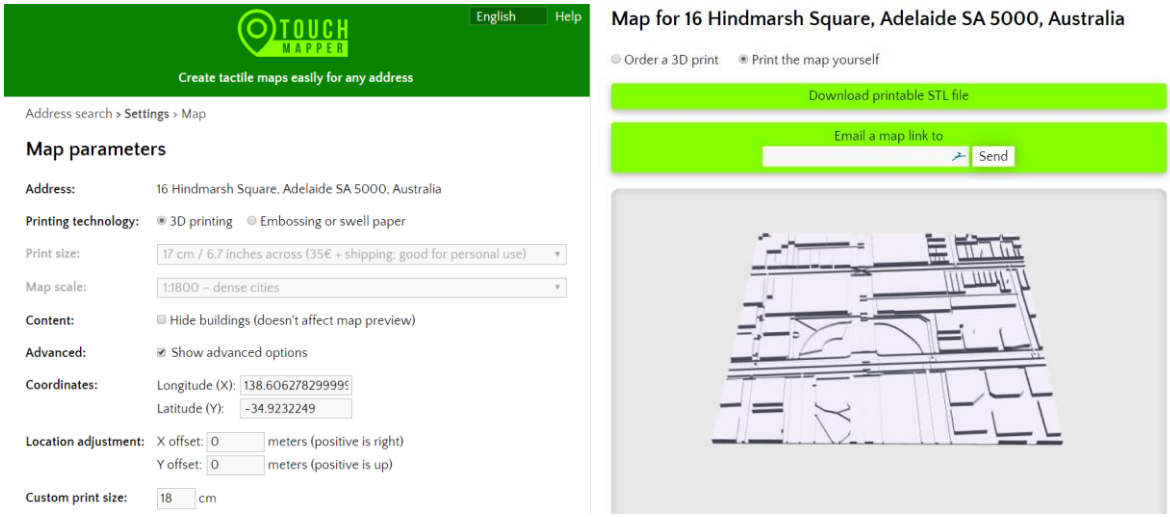
In the example shown below, we created a simple model taken from a NAPLAN-style question asking for a calculation of the number of squares. This question would be unreasonably difficult using a tactile graphic.



If you have designed a model that would be of interest to others, please do share it!

Design your own model

Touch-mapper.org is a free online website allowing you to very easily create tactile graphics or 3D printed models for street maps. Just type in the address, set the scale, and output for 3D printing, embossing or swell paper.



As Touch Mapper uses a fully automated process based on open street maps, the results are not always perfect. However, you can output the .stl file into another program such as TinkerCAD to add extra features or remove excess detail.

Brainstorming

Brainstorming activity

1. Think of a model that you would like for use in your classroom.
2. What are your design specifications?
3. Can you find the model you want online? Check Thingiverse.com, BTactile.com and conduct a Google search with .stl. Does the found model need any adjustments? Or do you need to create your own design?
4. Share your ideas

Brainstorming response

Based on your brainstorming ideas, let's try to:

- Find an existing model
- Make our own model in TinkerCAD

Getting started with 3D printing (continued)

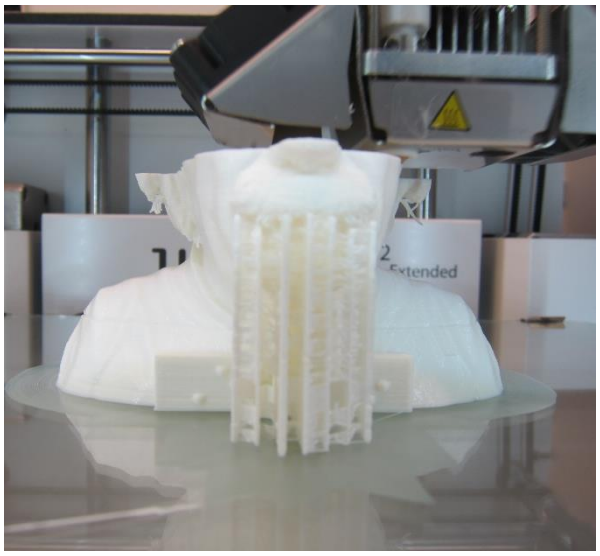
Design guidelines

- We are working on guidelines for:
    - Materials
    - Thickness
        - Minimum 0.8mm for bases
    - Heights
        - Minimum 0.2mm difference between adjacent items
        - Maximum 4cm height from base
    - Spacing
        - Minimum 1cm required between adjacent raised objects
        - Indented roads > 7mm wide
    - Textures
        - If printing from the top, use flat tops for a smoother finish
        - If you want curved shapes (like braille), print them on the side of the model

- Map symbols

Please email Leona.holloway@monash.edu if you are designing your own prints and would like to access and contribute to the draft guidelines.

Print



There are a wide range of materials to choose from when printing. PLA is easier to work with and more environmentally friendly. ABS is stronger and can be smoothed. Resin can give more detail and is smoother but it requires a different type of printer and the consumables are much more expensive.

After printing is complete, it may be necessary to removed supports and sand or file to remove sharp edges. ABS can also be placed in a chemical bath for a very smooth finish. You may also want to attach labels at this stage.

Getting involved

Getting involved

There are many ways that you can get involved in the project. We need your expert opinions and practical applications to ensure that the work is meaningful for the community.

- Respond to our survey on materials for early tactile literacy at http://accessiblegraphics.org/2019/12/18/survey/
- If you are teaching: Trial materials and provide feedback
- If you are designing/printing your own materials: Contribute to or test our draft guidelines
- Follow our progress at http://accessiblegraphics.org/research/3dprints/arc/updates/
- Contact us!

Contact us

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